MEMORY, HISTORICALLY AND EXPERIMENTALLY CONSIDERED.

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IV.

I.—*Recent Theories.*

The tendency of recent studies in physiology and pathology has been to establish the importance of physiological processes in all acts of retention and reproduction. Such studies have shown that, whatever be the ultimate relation of mind to body, memory is dependent upon physical processes. A cerebral process of some kind is the physical concomitant of an idea, and the condition of the reproduction of the idea is the repetition of the original cerebral process. In some way the brain centers are modified by impressions; they retain in growth the form of their modifications; and, on occasion of appropriate stimuli, they tend to repeat processes that have once occurred. The following passage from a recent article by a French psychologist illustrates some of the facts that enforce this view: "It is evident that there is in memory something automatic, capable of functioning alone. Even the diseases and illusions to which it is subject prove that there is something delicate and fragile in this marvel of natural mechanism. If a scholar, after having received a violent blow on the head, forgets all his knowledge of Greek without forgetting anything else, and if afterwards, as the result of a second blow, he suddenly regains his lost Greek, it is difficult to see in memory, with M. Ravaisson, an

act entirely spiritual. The automatic side of memory, especially of 'passive memory,' is illustrated by certain remarkable facts, where things have been preserved and reproduced with a facility that is at once perceived to be mechanical. When an imbecile in the asylum at Earlswood can repeat accurately a page of any book read years before and even without understanding it; when another person can repeat backwards what he reads as if he had under his eyes a 'photographic copy of the impressions received'; when Zukertort plays blindfolded twenty games of chess at once without considering anything but the imaginary chess-boards; when Gustave Doré or Horace Vernet, after attentively regarding their model, paint its portrait from memory; when another painter copies from memory Rubens' Martyrdom of St. Peter with an accuracy to deceive the experts, we conjecture that such accurate preservation and reproduction of the impressions received must have their causes in the organs."[1]

Some, however, among recent writers vigorously oppose any physical theory of memory. For example, Prof. Borden P. Bowne, the eminent American disciple of Lotze, maintains that "a physical explanation of memory cannot be found," and that "a mental explanation is equally impossible." Nevertheless, in some mysterious way the soul in its process of perpetual change "carries its past with it; not, however, in the form of latent modifications, but solely in the power of reproducing that past in consciousness."[2] Others, while emphasizing the

[1] From Fouillée's Le mechanisme de la mémoire, Revue des Deux Mondes, 15 Mai, 1885, pp. 359, 360.

[2] Metaph., p. 426. Ibid, p. 427. For a fuller account of Prof. Bowne's position, and a criticism of cerebral theories of reproduction, see Introduction to Psych. Theory, Ch. III, and Appendix to the same. Cf., also Ferri: La psychologie de l' association depuis Hobbes jusqu'à nos jours; and Huber: Das Gedächtniss.

importance of physical mechanism in retention and reproduction, maintain that the higher acts of conscious memory cannot be explained by physical processes. Thus Prof. Ladd, who holds that "the physical basis of memory as retentive is laid in the habit, or acquired tendency, of the elements of the nervous system,"[1] maintains that no physical conditions immediately concern the "mental activity which constitutes the essence of *conscious* memory."

"What is explained, if anything, is simply why I remember one thing rather than another — *granted the mind's power to remember at all.* This power is a spiritual activity wholly *sui generis,* and incapable of being conceived of as flowing out of any physical condition or mode of energy whatever."[2]

Fouillée also, after showing the dependence of memory upon physical processes, emphasizes the part that consciousness plays in a complete act of memory. He writes: "Not only consciousness, in its reflective form, has thus the power of reacting on the conservation and mechanical association of ideas, but also it is absolutely necessary to that third function which is the true characteristic of mental memory, the recognition of what is recalled. The automatism which we have described explains merely the revival of similar ideas and not their recognition as similar.... Memory is indivisibly physical and mental, physical for the spectator from without, mental for the spectator from within."[3]

Few if any will now be found to deny the dependence of memory in some degree upon cerebral processes. Even Prof. Bowne, with all his hostility to physiological theories of memory, admits that

[1] See Elements of Phys. Psych., p. 552.
[2] Ibid, p. 556.
[3] Loc. cit., pp. 388, 389.

"the brain conditions the mental activities of thought and recollection."[1] The ultimate nature of memory, especially in its function of recognition, being an inscrutable mystery, its physical side then appears the promising field for study. At all events most of the valuable contributions to the psychology of memory in recent years have been made by students in this field. Some of the theories that have resulted from their studies may be briefly mentioned here.

Accepting then the theory that memory — at least as retentive and reproductive — has a physiological basis, what is the physical mechanism that makes the persistence of an impression possible? This is a question that in recent years has divided physiologists. Three theories have been advocated. It is supposed (1) that memory depends upon a *movement* persisting in the brain; (2) that it depends upon a persisting *trace* or *residuum* in the brain; (3) that it depends upon a *disposition* persisting in the brain.

The theory that memory depends upon persisting movement has recently been advocated by Mr. Luys.[2] He calls that property of the nervous elements by virtue of which vibrations in them persist *phosphorescence*, since it seems analogous to that property of phosphorescent substances which causes them to remain luminous after the source of their light has disappeared. Luminous vibrations, as shown by the investigations of Niepce de Saint Victor, may be garnered up in a sheet of paper and by the use of proper re-agents, made to appear months afterward. The same persistence of vibrations is illustrated in the common forms of photography.

[1] Introduction to Psychological Theory, p. 113.
[2] The Brain and its Functions, Book II.

A plate of dry collodion retains for weeks the changes produced in it by exposure for a few seconds to the sun's rays. Similarly in memory, vibrations of an impression persist in the nervous elements, and to revive the impression it is only necessary that a suitable awakening agency renew the vibrations.[1]

The second theory, that memory depends upon a persisting trace, has long been a favorite one. Plato taught it in his figurative way. And among the moderns it has not lacked adherents since the days of the physiologist Haller. Among recent writers Oliver Wendell Holmes has eloquently illustrated it.[2] He deems the hypothesis probable, "that memory is a material record; that the brain is scarred and seamed with infinitesimal hieroglyphics, as the features are engraved with the traces of thought and passion."[3] A favorite illustration of this view has been the comparison of the brain in memory to a phonograph.[4] Like the tinfoil of the latter, the brain preserves a trace of impressions made upon it, and may be called a "conscious phonograph."[5]

Richet has advocated a form of the same theory,[6] and maintained that there is a great difference between the muscles and the nerves, since the effect

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[1] This theory merges into the second; and some writers do not clearly state which is their own view. Draper's illustrations may be taken in connection with either theory. See Conflict between Science and Religion, p. 132, seq.; also, Human Physiology, ch. xxi. The examples from photography also are often used to illustrate the second theory.

[2] Cf. Mechanism in Thought and Morals, p. 69 seq.

[3] Ibid., p. 77.

[4] See The Secret of a Good Memory by Dr. Mortimer-Granville.; also an article by M. Guyau, La Mémoire et le Phonographe, Revue Philosophique, March, 1880.

[5] M. Guyau, loc. cit., p. 322.

[6] Les origines et les modalités de la mémoire, Revue Philosophique, June, 1886.

of stimulation upon the former is transient, while upon the latter it is permanent. "In a word," he says, "while the muscles and the organic nerve-cell return completely to their original condition after an excitation, the psychic nerve-cell does not. It has been modified in a permanent manner by the act of stimulation; and this modification can be effaced only by the death of the cell. Each excitation has, so to speak, created a new cell different from the first." [1]

The third view — that the essence of memory is a functional disposition persisting in the brain — is, perhaps, the one most widely held by contemporary psychologists. Among recent writers Wundt[2] and Ribot[3] have been the most prominent exponents of it. But it is not new. Descartes taught it in a dim way.[4] Malebranche[5] and Bonnet[6] held substantially the same view, except that they thought of the disposition as persisting in the nerve fibres, while modern physiologists attribute the storing up of impressions especially to the nerve cells. Hartley's theory of vibratiuncules reminds one of Aristotle and seems to belong in our first class; but he also speaks of the persisting dispositions to these diminutive vibrations;[7] and some of his disciples appear to have held the same view. The theory has already been mentioned, but it may be summed up as follows: When a nerve cell, or a group of cells, receives an impression and reacts, it is modified in some way. There is, perhaps, a change in the molecular structure of

[1] Ibid,, p. 565.
[2] See his Grundzüge d. phys. Psych., Bd. II, ch. 17, p. 306 seq. 2 te Aufl.; also my 2d article, p. 261.
[3] See Diseases of Memory, Ch. I.
[4] Cf. my 1st article, p. 66.
[5] Cf. Recherche de la Vérité, II, v, 3; also my 1st article, p. 67.
[6] Cf. Analyse abrégée, ¶ X; also my 1st article, p. 79.
[7] See my 1st article, p. 82.

the cell—of what sort we do not know. It involves, however, an aptitude or disposition for reacting again in the same way. Just as the eye that is constantly practiced in comparing and measuring acquires an aptitude or skill that makes it far superior to the untrained eye. This is a functional, not an organic, change in the eye. In like manner every state of consciousness affects the nervous elements of the brain, and the nerve center is functionally modified so that the recurrence of the same mental state is rendered easier.

Ribot lays stress also upon the establishment of dynamic associations between the nerve elements.[1] The basis of memory, in his opinion, consists not only in the modifications effected in the individual elements, but also in the way various elements are grouped together to form a complex. In so simple a matter as the recollection of an apple, for example, these associations are necessary; for the recollection of an apple is the repetition in weaker form of the perception of the apple. This perception involves not only the retina and transmission along an extended route to the cortex, but association with the motor centers that control the movements of the eye; for it is owing to the latter that we perceive the apple as a solid body. The process of education renders stable these dynamic associations; and "a rich and well-stored memory is not a collection of impressions, but an assemblage of dynamic associations, very stable and very readily called forth."

These three theories, as held by recent writers, are closely related and merge in one another. The

[1] Loc. cit. Cp. also Wundt, loc. cit. These associations depend upon the general law, that when a nervous discharge has occurred along a certain path, discharge along the same path is rendered easier.

movement and the trace may cause the functional disposition. The functional disposition itself may, in the last resort, be due to persisting movement. At present it is impossible to say just what does occur. But the third theory, allying as it does the mechanism of memory to well-known physiological facts, and providing for the retention in growth and transmission to new cells, by a kind of heredity, of these acquired tendencies, presents fewest difficulties, and explains the facts perhaps as well as any.

In the second place, as has been often shown by recent writers, studies in physiology and pathology indicate that we have not memory, but memories. Each sense and organ of the body may be said to have its memory; and these memories are in a measure independent of each other. The visual memory may be lost without affecting the auditory memory. The memory of speech may be impaired and the general motor memories remain intact; and so on. Loss of any of these memories is due to disease in the appropriate center in the brain. Thus it appears that instead of one seat of memory as the older psychologists supposed, the different areas of the brain not only have their special office to perform in governing the organs of the body, but they are also the seat of the respective memories of those organs.[1]

[1] While many of the doctrines of localization are still disputed, few physiologists will deny that our various memories are scattered over the brain, the percipient organ, whatever it is, being also the remembering organ. Apart from physiology and the consideration just mentioned, the view has also been held quite frequently that we have memories rather than a faculty of universal memory. Cardinal Newman writes: "In real fact memory, as a talent, is not one indivisible faculty, but a power of retaining and recalling the past in this or that department of our experience, not in any whatever. Two memories, which are both specially retentive, may also be incommensurate. . . . . There are a hundred memories as there are a hundred virtues." Grammar of Assent, Am. ed., New York, 1870, pp. 327, 328.

The cases where men and animals have lost certain memories and then recovered them may sometimes be explained according to the hypotheses of Wundt and others, as follows: Around that area of the brain which functions any sense or movement is an area that might assume the same office. It is a *potential* area for the memories of that center. For when the actual center of any sense is destroyed a part of this potential area may be educated, so to speak, to perform the necessary functions. For example, if the actual sight area in the posterior part of a dog's brain be cut out, and the potential area remains, the dog becomes blind, but may recover. If, however, the potential area also be destroyed, the dog remains permanently blind.[1]

From what has been said the contrast will be clear between the old view, which made memory a distinct faculty and located it in a definite part of the brain and the modern doctrine of physiology which tends to consider memory as a function of all the cerebral centers.

The next problem that physiology has attempted to solve is in regard to the physical mechanism of the association of ideas. Psychologists from Aristotle down have generally been content with stating the phenomena of association. Modern physiological psychology asks: "Why do ideas recall each other according to the laws of contiguity, similarity, and contrast?"

Fouillée, following Herbert Spencer, has attempted to answer this question. In his opinion the two laws of similarity and contiguity[2] are, as far at least as the physical side is concerned, two expressions of the

[1] Cf. an excellent article by Dr. M. Allen Starr, "Where and How We Remember," Pop. Sci. Monthly, Sept., 1884. Some, however, maintain that the sight-center is not located entirely in the cortex.

[2] Contrast may be omitted as it is a subordinate principle.

same law. When two ideas are associated by contiguity, the physical mechanism is this: Two nerve-currents are aroused in neighboring parts of the brain. They are diffused according to the law of the persistence of movement until they meet and commingle. This union is the germ of habit or unconscious memory. It can, of course, take place only in case of nerve-currents in contiguous parts of the brain. The mechanism for association of similar ideas is the same; for adjacent parts of the brain are similar. Thus Fouillée agrees with Spencer that the prime law of association is this: "*Every presentation tends to associate with similar presentations on account of the identity of their seat in the brain.*" [1] All other laws are subordinate.

"Contiguity in time then," he says, "links things only by means of a contiguity in the extension of the brain. Thus are established in the nerve paths, as on the railroads, junctions, analogous to those where the switchman determines the course of the trains. The succession of ideas, even of those which we recognize afterwards as similar, is caused by the meeting, at the point of bifurcation, of two trains of images in contiguous parts of the brain. The words *entremets*, *entrecote*, *entrepont*, will mutually arouse each other by their point of bifurcation *entre*, and in some diseases the patient repeats these words mechanically one after the other." The cementing power is the persistence of force and the continuance of movement which communicates itself always to adjacent parts. All movement expends itself in one way or another. It cannot stop then, in a group of brain cells, but necessarily passes to neighboring groups, and persists even to the most distant groups through the connection of the association fibres.

[1] Loc. cit., p. 381.

Fouillée criticises Spencer, however, for confusing the mechanical process of joining similar images with the consciousness of their similarity. The latter is a mental synthesis. It occurs only between impressions presented automatically, but should be distinguished from the mechanical process of presenting such impressions. The reacting and synthesizing work of consciousness should be noted, especially in the complicated operation of recognizing the similarity between the past and the present. His position is summed up in the following passage:

"There is no contiguity, in our opinion, without similarity. Objectively, contiguity itself is a kind of similarity, under the relation of space and time; for it is a meeting in the same space and the same time which always tends to a certain fusion of movements the most opposite into a common form of movement. Subjectively, contiguity always becomes a certain similarity in consciousness. The mere fact of perceiving that disparate things *coincide*, as a bright light, a sound, a pain, is already a consciousness of similarity in the very bosom of difference. This judgment involves a reaction of consciousness in respect to sensations coming to it; and it is this reaction which constitutes the mental synthesis. This synthesis, without doubt, can occur only between terms already given by pure automatism, but consciousness perfects and renders permanent the cementing begun by simple mechanical coincidence. . . . . The brain takes note only of contiguity, of which similarity is a consequence; intelligence notes only similarity, of which contiguity is for it a simple kind and outline."[1]

Thus consciousness, according to Fouillée plays an important rôle in the association of ideas. It

[1] Loc. cit., pp. 382, 383.

reacts on presentations and arranges them harmoniously. While not the primitive force in association, it becomes, by reacting on associations presented to it, the force that dis-associates and analyzes. It has not only the negative power of rejecting ideas, but also the power of increasing by reflection the force of ideas suited to its purposes, thus making one idea a center of attraction, as it were, for other ideas.

In criticism of Fouillée's explanation of the physical mechanism of association, it may be said that it is too simple for an adequate explanation of the incalculable complexity of thought. The kaleidoscopic train of our ideas follows no such simple rules as the traditional laws of association. Fouillée himself, as well as Horwicz and others, has shown the part that feeling plays in the recall of ideas. Hodgson has done the same in showing that association by interest should be added to the other laws, and James gives cogent reason for adding a principle of spontaneous revival.

The importance of the last two principles will be seen by a moment's reflection. Not only does our mental constitution demand an adaptation on the part of ideas to the emotional mood of the moment, and thus our thoughts take a different course as we are sad or happy; but we find interest constantly shunting our thoughts into new channels. This can be readily shown by an illustration similar to those given by Hodgson and James. Suppose I am repeating the oft-quoted lines of Shakespere:

"Who steals my purse, steals trash," etc.

If none of the words suggest to my mind an idea of peculiar interest, I run through the passage without distraction. But suppose my pocket-book happens to be unusually empty and I know of no easy means of replenishing it. Then, when I come to the

word *purse*, I am likely to hesitate, and my thoughts will probably shoot off upon my financial condition, because that interests me more than Iago's reflections upon the value of a good name and the baseness of calumny.

In this case contiguity works with interest, but contiguity alone would carry my thoughts on without interruption to the end of the passage.

As an example of the spontaneous revival of images, Prof. James mentions the phenomenon sometimes observed before going to sleep when images dance in haphazard fashion before the eyes. This phenomenon occurs most frequently, perhaps, when we are weary; and it may be due, in part, to peripheral excitation. A case of more clearly mental revival seems to occur when we are well rested, and the nerve cells are, perhaps, overcharged with energy. At such a time it often happens that a multitude of images seem to spring up in the background of consciousness and to crowd around our conscious train. Our thought, to use a phrase of Fouillée's, seems to be a process of "intelligent selection." Of course it may be argued that, even in the case of this semi-conscious revival, there are subtle links of subconscious association, but there seems to be an element of spontaneity here, that is lost sight of in the ordinary doctrine of association.

Again the revival of our ideas is determined by the law of habit.[1] Modern studies add weight to the dictum of Bacon that "custom is the principal magistrate of man's life"; for they seem to show that our very thoughts chase each other along habitual paths. Except perhaps with men of genius, it is only in

[1] The relation of memory to habit has long been recognized. For a recent theory explaining memory by habit see Gratacap, Théorie de la Mémoire.

rare moments of special inspiration that our thoughts flash in unwonted channels.[1]

Hodgson has shown how habit works with interest in the spontaneous recall of our ideas.[2] "Two processes," he says, "are constantly going on in redintegration, the one a process of corrosion, melting, decay, and the other a process of renewing, arising, becoming. Unless by an effort of volition, which is here out of the question, (since here only the spontaneous train of thought is under consideration,) no object of representation remains long before consciousness in the same state, but fades, decays, and becomes indistinct. Those parts of the object, however, which possess an interest, that is, those which are attended by a representation of pleasure or pain, resist this tendency to gradual decay of the whole object. . . . . This inequality in the object, some parts, the uninteresting, submitting to decay, others, the interesting, resisting it, when it has continued for a certain time, ends in becoming a new object." This new object consists of the interesting parts of the old object and some sort of an indistinct environment. It is formed under the general law of redintegration, which is, as formulated by Hodgson, "that every object, which has occurred in a variety of combinations, has a tendency to redintegrate, or call back into consciousness, all of them."[3] These interesting parts which persist in consciousness then, as soon as the uninteresting parts of the old object have vanished, are free to unite with any object with

[1] The pathological activities of the mind are instructive upon this point. Paranoia is a case of extreme habituation. The patient has a bad habit of thought. For an excellent illustration of the way the thought of the paranoiac gravitates into one channel see a paper on Insistent and Fixed Ideas, by Edward Cowles, M. D. AM. JOUR. PSYCH. I, 222.

[2] Space and Time, p. 266 seq. Cf. also, Theory of Practice, vol. I, p. 367–381.

[3] Space and Time, p. 267.

which they have at any time been combined before. "All the former combinations of these parts may come back into consciousness; one must; but which will? There can be but one answer: That which has been most habitually combined with them before. This new object begins at once to form itself in consciousness, and to group its parts round the part still remaining from the former object; part after part comes out and arranges itself in its old position; but scarcely has the process begun, when the original law of interest begins to operate on this new formation, seizes on the interesting parts and impresses them on the attention to the exclusion of the rest, and the whole process is repeated again with endless variety."[1]

Such is the ceaseless interplay of habit and interest in our spontaneous trains of thought, and our voluntary thought seems still more complicated. It is not necessary to discuss the latter here; but it may be noted that in our ordinary trains of thought the spontaneous and the voluntary alternate, and thus the complexity is still more increased.

In the return of ideas to consciousness then, we find the laws of association modified by other principles, such as congruity with the emotional mood of the moment, habit, interest, spontaneity; and, in addition of course, by the recency and the vividness of the first impression. These are the factors that from the subjective standpoint seem to determine the train of thought in recollection, and it is natural to suppose that the corresponding physical processes are equally complex. The theory of Fouillée can afford but a partial explanation of them; all that can be done seems to be to express in the most gen-

[1] Ibid., pp. 267, 268.

eral terms the cerebral activity upon which recollection depends.

Prof. James has attempted to do this by showing how the laws of association "may follow from certain variations in a fundamental process of activity in the brain."[1] Basing his theory upon the principle that, when two brain processes have occurred simultaneously or in immediate succession, either of them on recurring tends to arouse the other also, and noting the complexity that arises from the fact that each elementary tract has at different times been excited in conjunction with *many* other tracts, and in view of the tension in nerve-tissue and the summation of excitements, he formulates the law of association from the physical standpoint as follows: "*The amount of activity at any given point in the brain-cortex is the sum of the tendencies of all other points to discharge into it, such tendencies being proportionate* (1) *to the number of times the excitement of each other point may have co-existed with that of the point in question;* (2) *to the intensity of such excitements; and* (3) *to the absence of any rival locality or process functionally disconnected with the first point, into which the discharges might be diverted.*"[2]

Another important work of modern psychology has been to show the relation of memory to the time sense. The metaphysical doctrine of the present as a knife-edge has no foundation in experience. Such a present, the mere conterminous of the past and future, may be a metaphysical reality, but it is a psychological nonentity. The only present of which we practically know anything is the immediately intuited past. "If the present thought," says Prof. James, "is of A B C D E F G, the next

[1] See The Association of Ideas, Pop. Sci. Monthly, March, 1880.
[2] Ibid., p. 582.

one will be of B C D E F G H, and the one after that of C D E F G H I,—the lingerings of the past dropping successively away, and the incomings of the future making up the loss. These lingerings of old objects, these incomings of new, are the germs of memory and expectation, the retrospective and the prospective sense of time. They give that continuity to consciousness, without which it could not be called a stream."[1]

The few seconds during which objects are fading from consciousness has been aptly named the "specious present" by Mr. Clay and Prof. James. The most vivid part of it is measured by the experiments on the *Umfang*, or extent of immediate consciousness for successive impressions.[2] Under the most favorable circumstances it may amount to some dozen seconds,[3] with perhaps an obscure background extending still farther into the past. It forms not only "the original paragon and prototype of all conceived times," by reference to which, the past and the future are measured, and without which we should probably have no sense of time, but its echoes of sensations just past make Fechner's memory-after-images possible[4] and constitute what Exner calls our "primary memory,"[5] and Richet our "elementary memory."[6]

That a stimulus leaves behind it an excitation that only gradually passes away is proved first by such facts as the possibility of perceiving an electric spark that lasts only a hundred-thousandth of a second,[7] the well-known fact of the summation of

[1] Wm. James: The Perception of Time, Journal of Speculative Philosophy, XX, pp. 375, 376.
[2] See Wundt: op. cit., Bd. II, p. 213 seq.
[3] Cf. Dietze's experiments, Philos. Studien, II, p. 362.
[4] See my 2d article, AM. JOUR. OF PSYCH., II, 253, 254.
[5] See Hermann's Handbuch d. Physiol., Bd. II, Thl. II, p. 281.
[6] Loc. cit., p. 562.
[7] Cf. Richet, loc. cit., pp. 561, 562.

stimuli, and the phenomena of sensorial after-images; secondly, by the vividness of the memory-after-image, which renders possible an accurate comparison of impressions. To quote again from Prof. James's admirable paper: "We may read off peculiarities in an after-image left by an object on the eye which we failed to note in the original. We may 'hark back' and take in the meaning of a sound several seconds after it has ceased. . . . . With the feeling of the present thing there must at all times mingle the fading echo of all those other things which the previous few seconds have supplied. Or, to state it in neural terms, there is at every moment a cumulation of brain processes overlapping each other, of which the fainter ones are the dying phases of processes which, but shortly previous, were active in a maximal degree. *The amount of the overlapping determines the feeling of the duration occupied.*" [1]

Many of the older writers were wont to say: "Our notion of duration, as well as our belief in it, is got by the faculty of memory." [2] This is true in a certain sense. Memory and the feeling of duration are inseparably connected; both alike seem to depend on the decaying processes — not only sensations but acts of attention and of thought as well — that fill the immediately intuited past. All that is necessary for the elementary form of either is the simultaneous presence of an active and a fading image. If a man were instantaneously created "with a brain in which were processes just like the 'fading' ones of an ordinary brain, the first real stimulus after creation would set up a process additional to these. The processes would overlap;

[1] Loc. cit., p. 401.
[2] Reid, Essays on the Intellectual Powers of man, Essay III.

and the new-created man would unquestionably have the feeling, at the very primal instant of his life, of having been in existence already some little space of time." [1]

The mysteries of memory and the sense of time are by no means solved, but the discussion has shifted from metaphysical to psycho-physic ground; and they who would study memory and the feeling of duration in their elementary form, must study the *Umfang* of consciousness.

Finally the feeling of personality depends upon memory. Or rather, with John Stuart Mill, we may say: "The phenomenon of Self and that of memory, are two sides of the same fact, or two different modes of viewing the same fact. We may, as psychologists, set out from either of them, and refer the other to it. We may in treating of memory, say that it is the idea of a past sensation associated with the idea of myself as having it. Or we may say, in treating of Identity, that the meaning of Self is the memory of certain past sensations." [2] Neither of these facts can be explained; but probably both alike depend primarily upon the persistence of sensations and the gradual fading of images. But neither would be complete without the revival of impressions. With the present perceptions mingle the memories of similar perceptions. If the object before us is a tree, the memories of other trees arise along with the sensations from it. With the impressions A, B, C, D, come the memories a_1, a_2, a_3, b_1, b_2, b_3, and so on. "Our consciousness is then," as Richet says, "always in the presence of a certain limited number of old images, that are always nearly the same, and

[1] James, loc. cit., p. 406.
[2] Note in his edition of James Mill's Analysis, Vol. II, p. 174.

these images being related to the same *me*, are the basis of the individual's personality — a personality that is rendered stable enough by the community of the images." [1]

Recent pathological studies have furnished some remarkable evidence for the view that memory and the feeling of personality are "two sides of the same fact." Whenever in disease, or somnambulism, or by hypnotic experimentation the old memory-images are shut out of consciousness, a new personality results.[2] If the conscious life is broken up into several memories, as many new personalities are improvised. It is not necessary to recount here the well-known hypnotic experiments at Paris, Nancy, and elsewhere; nor does space permit a discussion of the question whether the results of such studies affect the old notion of a transcendental self; but it is clear that the integrity of the personality depends upon the unity of memory, and anything that seriously affects the latter is likely to affect the former also.

II.—*Experimental Studies.*

The most important attempt to apply the methods of experimental psychology to the study of memory was made a few years ago by Dr. Ebbinghaus of Berlin. What he modestly calls the provisional results of his investigation are reported in a valuable monograph.[3] He experimented only upon himself; and, as he admits, his results have directly only an individual value. Nevertheless, his long and laborious series of experiments are so valuable both for their immediate results and as showing the advantages and limitations of psycho-physic methods in

[1] Loc. cit., p. 589.
[2] For examples cf. Ribot: Maladies de la personnalité.
[3] Ueber das Gedächtnis, Leipzig, 1885.

the study of memory, that a brief abstract of his work will be given here.

As the basis of his study Ebbinghaus lays down the principle that psychic states of every kind are not annihilated when they vanish from consciousness, but their effects persist unconsciously. Three classes of facts prove the persistence of states of consciousness apparently lost: 1st, in many cases we can *voluntarily reproduce* the lost states; 2d, what has once been present to consciousness, may return, sometimes after years, without any special effort, i. e., is *involuntarily reproduced;* 3d, vanished states of consciousness give evidence of their continued existence by rendering similar thought processes easier.

Great difficulties are encountered in experimenting upon memory. The conditions upon which a good memory depends vary with different individuals, and with the same individual from morning to evening, from youth to age. Moreover, much depends upon the content of the matter to be remembered. It is hard, for example, to remember forms and colors; and past states of feeling can be reproduced with difficulty. In the first place then, how shall the multitude of determining conditions be kept constant? In the second place, what numerical measure shall be found for anything so complex and evanescent as psychic processes? Ebbinghaus attempted to overcome these difficulties as follows.

From the simple consonants and the eleven German vowels and diphthongs all the syllables possible of a definite kind were formed, placing a vowel between two consonants. These nonsense syllables, about 2300 in number, were shuffled, and then, as they were drawn by lot, formed into series of different lengths. Several of these series were used at each experiment. The syllables were read

aloud repeatedly until it was just possible to recall them voluntarily. This end was considered attained "when a series, the first syllable being given, could be repeated by heart for the first time without hesitation, at a given rate of speed, and with the consciousness of perfectness."

This nonsense material has the following advantages. In the first place, it is relatively simple and homogeneous. While prose or poetry constantly changes in character, and varies in interest with the individual apperception, among more than 2,000 of these syllables, scarcely a dozen make any sense, and in the process of learning, the thought of this meaning is seldom aroused. The difference, however, between sense and nonsense syllables is not as great in this respect as would be expected *a priori*. For the varying content of the former is offset in case of the latter by predilections for different letters and syllable-combinations due to the influence of the mother-tongue. The advantage of nonsense material is considerable, however, in two other respects, namely, that it affords an inexhaustible amount of new combinations of similar character, and that it offers means for convenient quantitative variation.

In learning these nonsense syllables careful attention was given to details of method. A series was read through completely from beginning to end; then the first syllable was read, and the attempt was made to repeat the series. At the first hesitation the remainder was read, and then the repetition was begun anew. Reading and repetition were as nearly as possible at a uniform rate, namely, 150 syllables a minute, regulated by the ticking of a watch. The voice was kept at a uniform pitch with the accent upon every third or fourth syllable. After learning a series a pause of 15 seconds was

made to note results, and then the next series was attempted. Disturbances were removed, the attention concentrated, and the aim was to learn the series as quickly as possible. No attempt was made to bind the syllables by fancied relations. And, finally, care was taken especially that all the conditions of life during the period of experimentation should be as nearly uniform as possible. In the case of any great change in the mode of life, Ebbinghaus deferred the experiments, and a period of practice preceded their renewal. Similar experiments were performed at the same hour of the day, and care was taken that the activity preceding the experiments should be of the same character.

Two sources of error are noted by Ebbinghaus. First there are flickerings of the attention, or the like, that cause variations in the ability to repeat a series perfectly. These variations, however, may balance in a large group of series. The other possible source of error is a very dangerous one. It is the unconscious influence of theories and opinions of the experimenter. Even if he tries to avoid prejudice, that very effort is liable to vitiate the results. But, as the aim of the experiments was to obtain relative rather than absolute results, Ebbinghaus concluded that there was no reason to be very suspicious on this account.

The experiments were made at two periods, namely: 1879–80, and 1883–84, each period extending over a full year. Testing experiments of a similar kind preceded each period, so that in the results given the effect of growing practice may be disregarded. In the later period all the experiments were made between the hours of 1 and 3 p. m.; in the earlier one, they were divided unequally into three groups, performed between 10 and 11 a. m., 11 and 12 a. m., and 6 and 8 p. m.[1] By taking

[1] The latter groups will be designated A, B, and C respectively.

groups of an equal number of successive series separated by considerable intervals of time, the variations due to fatigue, fluctuation of the attention, and the like, were largely balanced. This detailed account of the method is necessary to a just estimation of the results to be detailed.

The first point is the dependence of the rapidity of learning a series upon the length of the same. It is well known that it takes a proportionately longer time to acquire a long series of ideas than a short series. Ebbinghaus's experiments corroborate this. He found that he could generally repeat a series of seven syllables after once reading them. Sometimes eight syllables could be repeated perfectly after one reading, six almost always; but about seventeen repetitions were required for a series of twelve, and nearly thirty for one of sixteen syllables. Of course these results have only an individual value; but it is noteworthy that for this experimenter they long remained constant.

By another group of experiments the process of learning poetry was compared with that of learning nonsense syllables. Stanzas from Byron's Don Juan were learned, and Ebbinghaus estimated that only about one-tenth the number of repetitions was required for learning material thus connected by the bonds of sense and rhythm.

The next important problem was the relation of retention to the number of repetitions. When a series once learned is forgotten, the strength of the impression persisting unconsciously can always be measured indirectly by the saving of time required for re-learning the series. To determine the effect of many repetitions upon the readiness with which a series can be reproduced, Ebbinghaus made seventy double experiments of which each experiment consisted in reading or repeating six sixteen-

syllable series a definite number of times, and then, twenty-four hours later, re-learning them. The experiments were divided into seven groups of ten experiments each, the number of repetitions in the seven groups being respectively 8, 16, 24, 32, 42, 53 and 64. The results are embodied in the following table,[1] the numbers being the number of seconds required for the re-learning.

	After 8 repetitions.	After 16 repetitions.	After 24 repetitions.	After 32 repetitions.	After 42 repetitions.	After 53 repetitions.	After 64 repetitions.
	1171	998	1013	736	708	615	530
	1070	795	853	764	579	579	483
	1204	936	854	863	734	601	499
	1180	1124	908	850	660	561	464
	1246	1168	1004	892	738	618	412
	1113	1160	1068	868	713	582	419
	1283	1189	979	913	649	572	417
	1141	1186	966	858	634	516	397
	1127	1164	1076	914	788	550	391
	1139	1059	1033	975	763	660	524
Mean.	1167	1078	975	863	697	585	454
Probable error.	±14	±28	±17	±15	±14	±9	±11

The average time for the first learning of six series of sixteen syllables each, as estimated from fifty-three experiments was 1270 seconds, with the small probable error of $\pm$ 7. Comparing with this the times required for re-learning as given in the table, Ebbinghaus estimates that, on an average, in re-learning there is a saving of one third due to the persisting after-effect of the repetitions. In other words for every three repetitions to-day a person is saved about one repetition twenty-four hours afterwards.

The same experiments show the relation of recognition to the number of repetitions. When the series were impressed upon the mind with only eight

[1] Op. cit. p. 75.

or sixteen repetitions they were not recognized on the following day. When, however, there were fifty-three or sixty-four repetitions, they generally were recognized.

Further experiments indicated that this saving does not continue in the same ratio when the number of repetitions is increased above sixty-four. If for each repetition one third its value is saved in learning the series the following day, then it would seem that, if a series is repeated three times as much as is necessary to learn it, it should be possible to recall the series the next day. But even with four times the number of repetitions, this proved impossible.

A still more important group of experiments showed the relation of retention to time. 163 double experiments were performed. Each experiment consisted in learning and re-learning eight thirteen-syllable series. The re-learning was done at seven different intervals, approximately as follows: one-third of an hour, one hour, nine hours, one day, two days, six days, and thirty-one days. The learning was continued until it was possible to repeat a series twice without error. The time was measured from the completion of the learning. The results appear in the following table.

Time interval.	No. of seconds required for first learning.	No. of seconds required for re-learning.	Gain in seconds.	Gain in per cent.	Probable error.
19 min.	1081	498	583	58.2	1
63 "	1106	647*k*	459	44.2	1
525 "	1132	752*k*	380	35.8	1
1 day A	1109	756	353	33.8	2
" B	853	599	254	32.6	2.2
" C	1184	803	381	34.6	2.3
2 days A	1154	854	300	27.2	2.3
" B	891	647	244	28.2	3.5
" C	1245	917	328	28.1	1.8
6 days A	1090	834	260	25.2	1.9
" B	872	652	220	26.1	4
" C	1306	989	317	24.9	1.6
31 days A	1115	892	223	21.2	1.3
" B	879	710	169	20.8	1.4
" C	1261	1007	254	21.1	2.7

Examination of the table[1] shows that the process of forgetting is rapid at first and then slower. After the interval of an hour so much has been forgotten that more than half the original work must be done again before the series can be reproduced. After eight hours almost two thirds of the original work is necessary. But from that point the process of forgetting proceeds more slowly. After twenty-four hours the impression still retains about a third of its original strength; after six days, a quarter; after a month, still a full fifth. It is noteworthy

[1] Op. cit. p. 94 seq. Ebbinghaus gives tables for each group of experiments. I have collected in this table the *mean* results only.

A, B and C designate experiments performed at the hours of 10—11 A. M., 11—12 A. M. and 6—8 P. M. respectively. In estimating the per cent. of saving, the time for the final two perfect repetitions, i. e., 85 sec., was deducted from the time for learning as given above. The figures followed by *k* in the 2d and 3d groups give the corrected times for re-learning. As there was an unavoidable variation in the conditions due to the increased fatigue at the time of re-learning in the later hours of the day, a number of seconds were deducted from the original results.

that, while the impression made by nonsense syllables is so evanescent that a series once perfectly learned is forgotten after an interval of twenty minutes, a residuum of some sort persists for a long time, so that even after a month the same series can be re-learned in four fifths of the time originally required. A general statement of the results is as follows: The ratio of what is retained to what is forgotten is inversely as the logarithm of the time[1].

Another group of experiments showed the interesting result, that a long series is more strongly impressed upon the mind by once learning than a short series. For example, a series of thirty-six syllables is nearly twice as firmly impressed as one of twelve syllables.

Further experiments showed that when there are a large number of repetitions a suitable distribution of them over a certain interval of time is more advantageous than the accumulation of them all at once. Thus in learning nine twelve-syllable series the same impression was made by thirty-eight repetitions distributed over four successive days as by sixty-eight consecutive repetitions.

Ebbinghaus experimented also upon the association of ideas by contiguity. This law of association is generally formulated as follows: Presentations once aroused in consciousness simultaneously, or in immediate succession, reproduce each other, and more easily in the direction of the original succession, and with greater certainty the oftener they have been together. But one point may be mooted. When a series *a b c d e f g* has been learned, does *a*

[1] Ebbinghaus's formula was:

$$\frac{\textit{das Behaltene}}{\textit{das Vergessene}} = \frac{K}{(\log. t)c},$$

in which K and c are individual constants.

recall *b*, and *b* recall *c*, and so on, each member of the series being connected only with the succeeding member; or does *a* recall *b*, and tend also to recall *c*, *d*, and the rest, each member being associated not only with the succeeding member but also, though in a less degree, with the whole series? The Herbartians maintain that the latter is true for so many members of the series as have once been together above the threshold of consciousness.[1] To bring this problem to a scientific test, Ebbinghaus performed the group of experiments next to be described.

When a series of nonsense syllables is learned by heart, and re-learned in the same order on the next day, there is, as we have seen, a saving of about one third the original work. This one third measures the strength of the association from one member of the series to the succeeding member. Suppose the syllables are re-learned in a different order; what will be the result? Fifty-five double experiments were performed to determine this point. Six sixteen-syllable series were employed in each experiment. If the different series are represented by Roman, the syllables by Arabic numerals, the series employed would be as follows: $I_1\ I_2\ I_3 \ldots\ldots I_{15}\ I_{16}$, $II_1\ II_2\ II_3 \ldots\ldots II_{15}\ II_{16}$, and so on. New series were formed by Ebbinghaus from the alternate syllables as follows: $I_1\ I_3\ I_5 \ldots\ldots I_{15}\ I_2\ I_4\ I_6 \ldots\ldots I_{16}$. Except in the middle, where there is a break, each syllable of the transformed series was separated from its present neighbor by an intervening member in the original order. If these intervening members were essential hindrances to the bonds of association, then the new series is as good as

[1] See Herbart's Lehrb. z. Psychol., §29; also my 2d article, AMERICAN JOURNAL of PSYCHOLOGY, II, 248.

unknown; and one can expect no saving of labor in learning the transformed series. If, on the contrary, the bonds of association extend not only from one member to the succeeding members, but also over intervening members to more distant syllables, then there will be a certain predisposition to the new series. The succeeding syllables of the series will still be united to each other with a certain strength, and less work should be required to re-learn them than to learn an entirely new series. The amount of this saving will be a measure for the strength of association over intervening members. If series are derived by skipping two, three or more syllables, the same considerations apply to them. Ebbinghaus derived similar series by skipping two, three, and seven syllables. Skipping seven, the derived group of series was as follows: I_1 I_9 II_1 II_9 III_1 III_9 IV_1 IV_9 V_1 V_9 VI_1 VI_9, I_2 I_{10} II_2 II_{10}, and so on, the last series being V_7 V_{15} VI_7 VI_{15} I_8 I_{16} II_8 II_{16} III_8 III_{16} IV_8 IV_{16} V_8 V_{16} VI_8 VI_{16}. By examining series derived in this manner, it will be seen that the breaks increase with the increasing number of syllables skipped. Where the different series are mixed, there is no association except between syllables that originally were in the same series. Hence, the derived series suffer from a certain unavoidable inequality.

Each experiment consisted in learning the six original series; and then after twenty-four hours re-learning them in the derived order. The result showed a remarkable saving of time in re-learning the series. Skipping one, two, three, and seven syllables, the mean saving in learning the derived series was 152 sec., 94 sec., 78 sec., and 42 sec., the mean time for learning the original series being 1266 sec.

The objection may be raised that the syllables

are impressed upon the mind by the first learning, not only in their definite order, but also as separate members. With reference to this objection, Ebbinghaus experimented, retaining the initial and final syllables of the six original series employed in an experiment, and using chance combinations of the other eighty-four syllables. In the case of series formed thus by mere permutation, the mean saving was only 12 sec., the mean time for learning the original series being 1261 sec.

Again, it may be objected that the saving of time in re-learning was due to an unconscious desire to bring about this result. In case of the first two or three re-arrangements, the saving is so considerable that it could hardly be due to any such influence. Then too, the regular decrease in the numbers would hardly occur if that were the case. Nevertheless, to test this point, thirty experiments were made in the following manner:

Six sixteen-syllable series were written upon a sheet of paper. On the back side of the sheet six derived series were written. Six sheets were thus prepared for each of the five transformations described above, making 30 in all. The sheets of each group could not be distinguished from each other on the front side; and they were shuffled and laid aside until the memory of what individual syllables occurred in a given derived series had vanished. Then the series on the front side of one sheet of paper were learned; and after twenty-four hours those on the back side of the same sheet. The time necessary for learning the separate series was noted, but the results were not reckoned up until the whole thirty sheets had been finished. Then these experiments were found to corroborate the results of the earlier ones. Skipping one, two, three, and seven syllables, the saving in learning the derived series was 110

sec., 79 sec., 64 sec., and 40 sec. respectively, the mean time for learning the original series, as before, being about 1266 sec. Deriving the new series by permutation, the re-learning required a mean application of 5 sec. more than the original learning, the mean time for the latter being 1261 sec.

Putting the two sets of results together to obtain a possible balance of disturbing influences, Ebbinghaus estimates the results of the eighty-five experiments in percents as follows.

Strength of association, as measured by the saving of time in re-learning six sixteen-syllable series:

Between contiguous members	33.3	per cent.
Skipping one syllable	10.8	"
" two syllables	7.0	"
" three "	5.8	"
" seven "	3.3	"
With permutation	0.5	"

Ebbinghaus emphasizes the interesting fact that, when the derived series were formed by permutation of the syllables, retaining only the initial and the final members of a series, no saving was shown. The new series formed of the identical syllables originally used could be learned in scarcely less time than an entirely new series. But a series derived by skipping seven syllables could be learned in noticeably less time than an entirely new one. As seven was the number of syllables that Ebbinghaus could learn by a single repetition, it might seem that the associations described were due to the fact that seven syllables were embraced in consciousness at once. But seven syllables were skipped, thus showing association between the first and the ninth members of a series. Moreover the numbers representing the strength of the association were so great and the gradation of them of such a nature, that it seems probable that the bonds of association extend even to more distant members of the series. If

there are associations, argues Ebbinghaus, extending to more syllables than can be embraced in one act of consciousness, then these associations cannot be explained simply on the theory that presentations included in one act of consciousness tend to arouse each other.[1]

He also experimented to determine whether there are bonds of association extending backward. He took six sixteen-syllable series and made ten experiments with series derived by mere inversion of the syllables, and four with series derived by inversion and skipping one syllable. In the first case the saving in re-learning amounted to 12.4 per cent.; in the last to 5 per cent.

Further experiments were made to determine the effect of many repetitions. The result showed that while an increased number of repetitions strengthens all the associations, the stronger bonds between neighboring members of a series are strengthened more rapidly than the weaker ones between remote members.

The general results of this whole study of association are summarized as follows:

"In the impressing and strengthening of a series of ideas by numerous repetitions of the same, inner bonds or associations are formed between all the individual members of the series. Every member of the series preserves a certain tendency in case of its return into consciousness to bring the other members with it.

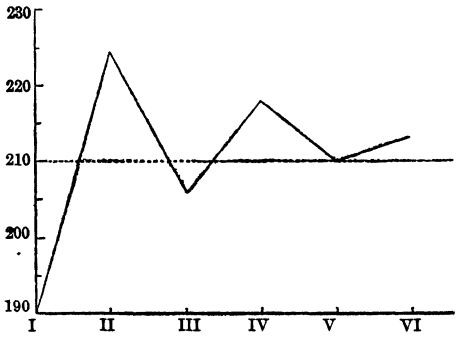
"These bonds or tendencies are of different degrees of strength in several respects. For the remote members of the original series they are weaker than

[1] Compare Wundt's experiments on the *Umfang* or extent of immediate consciousness for successive impressions, Physiol. Psych., 2te Aufl., Bd., II., p. 213 seq.

for neighboring members, for definite distances backward, weaker than for the same distances forward. In case of increasing number of repetitions the strength of all the bonds increases. But the already stronger bonds between the neighboring members are by this means considerably more quickly strengthened than the weaker bonds between more distant members. Therefore the more the number of repetitions increases, so much the stronger become absolutely and relatively the bonds of the members immediately succeeding each other, and so much the more exclusive and predominant becomes the tendency of each member when it returns into consciousness to bring after it that one which in the repetition always immediately succeeded it."[1]

From the study of his results Ebbinghaus found indication of a remarkable rhythm of the attention. A series learned in a proportionately short time was followed as a rule by a series learned in a relatively long time. "There seems to be," he says, "a kind of periodic oscillation of the mental susceptibility or of the attention, in which the increasing fatigue appears in variations about a gradually shifting middle position."[2] Nearly all the experiments showed this oscillation. The results of a typical group of experiments were as follows: In eighty-four experiments with six sixteen-syllable series the mean time for learning the 1st series was 191 sec.; for the 2d, 224 sec.; for the 3d, 206 sec.; for the 4th, 218 sec.; for the 5th, 210 sec.; for the 6th, 213 sec. Representing these results diagrammatically with the number of seconds marked off on the ordinates and that of the series on the abscissas, the curve will be the following:[3]

[1] pp. 160, 161.
[2] p. 60.
[3] p. 58.



In experimenting with derived series, however, the phase of the rhythm was changed, and the even numbered series were learned quicker than the odd.[1]

Such in brief outline are the results of Ebbinghaus's laborious and painstaking experiments. Fully to appreciate his scientific rigor and subtle analysis one must read his own work. Some of his experiments have revealed wholly new facts, and others have added a most needful accuracy to what was indefinite. To the latter class belong the experiments on the unconscious persistence of impressions. Thoughtful observers have believed that things forgotten were not wholly lost; the Herbartians have imagined a mysterious subconscious glimmer in the soul; Richet a trace in the brain substance; Luys and others a persisting vibration; Maudsley a

[1] Ebbinghaus explains this by an ingenious hypothesis of indirect, unconscious association. When the first derived series, made up of syllables 1, 3, 5, etc., is learned, there is a tendency for these syllables to bring with them also syllables 2, 4, 6, etc., though too weak a one to bring them into consciousness — merely an inner excitation, such as occurs when one tries in vain to recall a forgotten name. This, however, strengthens the sub-conscious bonds of the even numbered syllables, and if the derived series which they form is learned *after* that composed of the odd syllables, it is learned more easily. "Inner bonds are formed between successive syllables unconsciously aroused, as between successive conscious syllables, only of course of less strength." — (p. 168.)

"neurotic pattern"; James a "path of association"; Ribot and Wundt a "functional disposition"; and some of the intellectualists have given up the attempt to name it altogether. But whatever it is, the experiments of Ebbinghaus bring it under the yoke of numerical determination. The curve of forgetting for long periods of time has also been determined; and the work upon association has put an experimental foundation under the Herbartian doctrine that each member of a series is linked not only to the following member, but also in lessening degrees to those more remote.

All psychophysic experiments, especially those requiring comparison and those upon the time-sense and the like, involve memory. The experiments of Wundt[1] and his pupils[2] upon the *Umfang*, or extent of immediate consciousness of successive impressions, concern directly what Richet calls the "elementary memory".[3] But to Ebbinghaus belongs the credit of first performing a series of scientific experiments with special reference to the phenomena of memory. His success in testing, by an indirect method, the association of ideas in a series, suggests the possibility of extending the experimental method to apparently inaccessible psychological problems. Useful as his method proved, it was not, however, the simplest one. The learning of nonsense syllables is a complicated psychological process; and while such syllables are free from the associations that cluster about significant material, nevertheless, some syllables are easier than others on account of the eye and

[1] Op. cit., p. 213 seq.

[2] Especially Dietze, Untersuchungen über den Umfang des Bewusstseins bei regelmässig aufeinander folgenden Schalleindrücken, Phil. Studien, II., 362—394. Also Cattell, Ueber die Trägheit der Netzhaut und des Sehcentrums, Phil. Studien, III., 94—127; and Hall and Jastrow, Studies in Rhythm, Mind, XI., 55—62.

[3] Loc. cit., p. 568.

ear memories and the muscle memory of the vocal organs. A simpler method is to test the power of recognizing a sense-impression when repeated. It is a well-known fact that such recognition is easier than ordinary recollection without repetition of the external impression. Thus we distinguish many more shades of color than we can picture in imagination; and we generally can understand more words of a language than we can use. H. K. Wolfe adopted this simpler method in investigating the memory for tones. He experimented as follows.[1]

Nearly 300 vibrating metal tongues, giving notes through five octaves, were used. A tone was given, and after an interval determined upon beforehand, either the same tone was repeated or a higher or lower one was sounded. The listener wrote one of two answers—"same" (*gleich*) or "different" (*verschieden*). If the answer was the latter, a further judgment was made whether the second tone was higher or lower than the first, or the subject could answer "doubtful." The difference of tone amounted to 4, 8, or 12 vibrations a second, and was kept constant during a group of experiments.

The main point of the research was to determine the influence upon memory of the time-interval between the impressions to be compared. This was varied from one second to 30, 60, or 120 seconds. The greatest accuracy was found when the interval was about two seconds. Three reasons, he thinks, may account for the failure to judge correctly when the interval is less than this: 1st, as we are apt to overestimate short intervals of time the attention may not be focused when the second sound is heard; 2nd, there may not be time, when the interval is very short, fully to perceive the two impressions; or 3d, it is possible

[1] See Ueber das Tongedächtniss, Philos. Studien, III., 4.

that an excitement of the sense-organ persisting from the first impression intensifies the second, and hence the latter is incorrectly perceived.

As the time was increased beyond two seconds, his experiments showed that the curve of memory fell pretty regularly until the interval reached a point somewhere between 10 and 20 sec. Here with each subject Wolfe found a point where forgetting seemed to be retarded or to cease altogether. In case of W. and L., the two subjects with whom the largest number of experiments were made, this swell in the memory-curve occurred, with the former, at an interval of about 15 sec., with the latter at an interval between 20 sec. and 25 sec. Beyond this point the curve falls off still more rapidly with increasing time. But some of the subjects showed traces of possibly a second swell in the curve at an interval from 30 sec. to 50 sec. While smaller irregularities in the curve disappeared with a larger number of experiments, over 4,000 experiments in case of L., and 12,000 in case of W., showed the first retardation point tolerably clearly.

The results in case of these two subjects with whom the largest number of experiments were performed, may be expressed approximately, as Wolfe estimates, in the following simple mathematical formula: The ratio of the right and wrong cases is inversely proportional to the logarithms of the time-intervals[1].

[1] Letting r = the correct judgments, f = the errors, and K and c = individual constants; the formula is

$$\frac{r}{f} = \frac{K}{\text{Log. } t} + c,$$

or

$$r = \frac{Kf}{\text{Log. } t} + cf.$$

Ebbinghaus's formula was similar. (See *supra*). It is an interesting question whether this law would hold with other experimenters and for all the senses. Dr. Jastrow found in testing the eye and hand

Thus Wolfe's experiments with short intervals corroborate those of Ebbinghaus with longer periods.

The results of Ebbinghaus's study, as has been said, have primarily only an individual value. So far as I am aware, there is no record of any adequate attempt to test these results with many different individuals. A pupil of Kraepelin, however, Dr. Oehrn, has made a suggestive study of individual psychology[1]; and in reference to memory he used substantially the method of Ebbinghaus, although in part substituting number series for nonsense syllables. But his experiments thus far reported have given no satisfactory results as far as memory is concerned, except to corroborate the testimony of others, that in the performance of any mental function there are great individual variations, and to show that in such experiments the mean variation is a direct measure of the share of the attention in the process. Thus, in learning the tedious nonsense syllables, the average mean variation for his ten subjects was nearly six times as large as in the more interesting process of adding[2].

Upon one point, however, the experiments of Ebbinghaus have been supplemented by a research

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memories for measurements, that "in both cases the memory is extremely accurate and is almost as faultless after the lapse of a few days as of a few minutes." See The Perception of Space by Disparate Senses, Mind, XI., p. 552. The same article contains experiments upon the relative accuracy of the eye-arm-and-hand memories for space perceptions.

Beaunis has reported the provisional results of somewhat similar experiments upon muscular sensations. He found three phrases in the vanishing of muscular memory when tested by the power to reproduce the extent and direction of movements: 1st, *the phase of conscious memory;* 2d, *the phase of unconscious memory,* where conscious memory has vanished, but it is still possible to reproduce the given movements; 3d, *the phase of total obliviscence.* See Rev. Philos., XXV, pp. 369—574.

[1] Experimentelle Studien zur Individualpsychologie. Inaug. Dis. Dorpat, 1889.

[2] See review of his paper in the experimental section of this number. ED.

upon many individuals. Mr. Jacobs and Mrs. Bryant have tested the powers of school children in reproducing numerals and letters after once hearing them[1]. Their most important experiments were performed with the boys of the Jews Free School and the girls of the North London Collegiate School. Numerals (omitting *seven*) and letters (omitting *w*) were employed as more uniform in pronunciation and rhythm than nonsense syllables. The letters or numerals were dictated *once* in a monotonous tone at the rate of 120 sounds a minute, and the pupils repeated orally or wrote as accurately as they could the series given. The following are the most important results of this interesting research.

In the first place, the mental "span"—as the experimenters called the ability measured by the maximum number of syllables that could be repeated after once hearing them—showed a decided increase with the age of the pupils. Boys of 11 years could repeat in this way 6.5 numerals and 5.5 letters; of 12 years, 6.8 numerals and 5.7 letters; of 13 years, 8.8 numerals and 7.9 letters. The following table shows the results of a large number of observations at the girls' school:—

Age,	8	9	10	11	12	13	14	15	16	17	18	19
Number of subjects,	8	13	19	36	41	42	42	72	66	50	30	14
Average number of numerals,	6.6	6.7	6.8	7.2	7.4	7.3	7.3	7.7	8	8	8.6	8.6
Average number of letters,	6	7	6.6	4.6	6.5	6.7	6.7	7.4	7.9	7.3	8.2	7.9

Again the relation of this mental span to the pupil's rank in the class was clearly marked. "As a rule high span went with high place in the form." In a class of twelve-year-old boys the average span for numerals was 9.1 for the first ten, 8.3 for the next

[1] Mind, XII, pp. 75 seq.

and 7.9 for the lowest ten. In another class of thirty boys of the same age, the first ten could grasp 7.6 numerals, the second ten 7.1, and the lowest only 6.3.

Similar results were found at the girls' school. The first half of a class usually showed a higher span than the second half.[1]

Mr. Galton, Prof. Bain, and Mr. Sully made similar observations on the memory-power of idiots. Nine of the best girls among the inmates of one asylum were tested with numerals. One could recollect 2 figures, one 3, three 4, and the remainder 5. And at another asylum where the inmates were of higher mental capacity, some were found with a higher span.

Oliver Wendell Holmes experimented in this manner some years ago[2], and was surprised to find how frequently mistakes are made in repeating between seven and ten figures or letters. An individual may sometimes be found, he says, who can repeat a larger number, and he refers to the famous cases on record where persons have repeated sixty or more unconnected words after once hearing them[3]. But the latter, apart from a few anomalous cases, are hardly to be considered here; for usually the words are repeated slowly and the hearer links them by mnemonic devices.

The amount of this memory-span evidently bears some relation to the mental capacity; and Dr. Holmes has suggested that in such experiments we have "a very simple mental dynamometer which may yet find its place in education."[4] Certainly this

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[1] Dr. Cattell found that a distinct shortening of the time required for the mental process of association accompanies growth and education. See Mind, XIV, p. 234.

[2] Op. cit., p. 32.

[3] For an account of cases of remarkable memory see Huber, op. cit., p. 36 seq; also Jour. of Spec. Phil., V, pp. 6–26.

[4] Loc. cit, p. 33. Mr. Jacobs makes the same suggestion. See loc. cit., also Mind XI, p 54.

test or some other direct observation of memory should be used as a test for cerebral fatigue; for experiments show that memory is very sensitive to changes in physical condition.[1]

Much experimental study has been devoted to the association of ideas. The most extended researches have been made by Trautscholdt[2] and Cattell.[3] The former sought to determine the time required to perform an ordinary act of association, and classified the results of a large number of experiments according to the nature of the association. The latter has extended the research to various forms of association, and has obtained further statistics of its nature. These important studies are too well-known to require extended comment. But as yet, valuable as they are, they have thrown no great light upon memory; for the experiments have been comparatively few in each form of association investigated; and in such experiments, the mental processes measured are inevitably complicated, voluntary recollection being mixed with spontaneous, and both with acts of judging.[4] They are, however, suggestive; they illustrate the complexity of the process of association, and show the important rôle of obscure processes in reproduction.

The average time for the mental process of association was found by Trautscholdt to be 0.727 sec. It is noteworthy that this time is approximately the interval that numerous observers have found can be most accurately reproduced. From this fact

[1]Cp. one of Galton's tests: La fatigue mentale, Revue Scientifique, Jan. 26, 1889, p. 101.

[2]Philosophische Studien, I, p. 213 seq.

[3]Reported in Mind, XII, pp. 68—74 and XIV, pp. 230–250. Cf. also his earlier experiments on the time required for verbal operations; Mind, XI, pp. 63, 220,, 377, 524.

[4]Cp., the remarks by Cattell's subjects, Mind, Vol. XIV, p. 244 seq. See also Dr. Münsterberg's criticism of Trautscholdt's experiments, Beiträge z. experimentellen Psychologie, Heft 1, p. 87 seq.

Wundt concludes "that a rate of about three fourths of a second is that at which processes of association are most easily performed, and which therefore, in the reproduction of objective time-intervals we involuntarily seek to equal by shortening longer periods and lengthening shorter ones.[1] Remarkably enough this time nearly corresponds to the time required for the swinging of the legs in rapid walking. It does not appear improbable that both the psychic constants of the average speed of reproduction and of the most accurate time estimate have been formed under the influence of the most habitual bodily movements, which have also determined our inclination to divide greater periods of time rhythmically.[2]"

Dr. Alfred Lehmann, of Kopenhagen, has studied another aspect of the subject,[3] and attempted to prove that all association can be explained by the single law of contiguity. Like Wolfe, he employed the method of right and wrong cases, and tested the power of recognition; but he experimented with sensations of color, using different shades of gray produced by means of rotating disks, partly black and partly white. In part his experiments supplement the work of Wolfe, and tend to show that the same laws apply to recognition by sight as by hearing; for, varying the time-interval, from 5 sec. to 120 sec., five series of 30 experiments each showed that as time increased, the number of correct judgments decreased with one observer from 30 to 17; with the other from 21 to 17. The experiments give some support to the author's thesis in regard to the laws of association.

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[1] Cp., however, the experiments reported by Stevens, Mind XI, p. 393 seq.

[2] Op, cit., II, p. 286. But see also Galton, who used a different method and found the rate of association to be about 50 ideas a minute; Enquiries into Human Faculty, p. 188 seq.

[3] Ueber Wiedererkennen, Philos. Studien, V, 96—150.

Among experimental methods should also be mentioned hypnotic tests of memory. Perhaps the most important result of these studies has been to demonstrate the existence and importance of what Bernheim calls "latent memories,"[1] which account for the performance of suggested acts after long intervals of time. Space is not left for us to consider here the relation of memory to the hypnotic sleep; but an account of the main facts may be found in the works of Delbœuf,[2] Janet,[3] Bernheim[4] and others, and in the convenient little résumé by Dr. Dichas.[5]

III.—*Conclusion.*

In this brief study of memory from the earliest mythology to recent experimental researches, representative philosophers have been chosen. If the more idealistic and transcendental theories may sometimes seem to have been slighted, it is because an adequate presentation would lead too far into metaphysics rather than lack of appreciation of them. The aim has been to avoid the wider region of philosophical inquiry, upon the borders of which we have repeatedly found ourselves. Still, limiting our inquiry, a multitude of problems arise. Apart from the special questions of cerebral localization,[6] of the trustworthiness of memory, the relation of memory proper to habit or organic memory, the unity of personality, the nature and conditions of "latent

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[1] De la suggestion et de ses applications à la thérapeutique, I., Ch. VIII. Paris, 1886.

[2] La mémoire chez les hypnotisées, Rev. Philos., May 1886, p. 441 seq.; also Le sommeil et les rêves.

[3] L'automatisme psychologique, Paris, 1889; also Rev. Philos., XXV., pp. 238–279.

[4] Op. cit.

[5] Étude de la mémoire dans ses raports avec le sommeil hypnotique. Paris, 1887.

[6] For an enumeration of important problems concerning aphasia see The Pathology of Sensory Aphasia, by Dr. Starr. Brain, July, 1889, pp. 95, 96.

memories,"[1] and the processes that occur on the borderland between memory and habit,[2]—apart from these and the more technical questions that cluster around the pathological and biological aspects of the subject, there are yet others. What is the relation of the sensorial after-image, to the memory after-image and of the latter to the ordinary mental image? What are the time-limits and physical conditions of the primary memory? Are the phenomena of recurrent sensations mentioned by Henle and Fechner due to peripheral or central causes? What is the relative accuracy of memory in the field of the different senses? Is there a rhythm in retentiveness as such, or are the variations in the curve of forgetting like those found by Wolfe due to fluctuations of the attention and the like? Do we always remember forwards and not backwards?[3] What are the obscure links in the process of association that the associationist atomism loses sight of? What is the nature of that matrix of presentations which Mr. James Ward calls the "presentation continuum?" and what its relation to the "memory continuum?"[4] Can the memory as such be trained, or do so-called memory-exercises really train only the attention?[5] What degree of memory have animals? What is the genesis of memory in children? and what the relation of great memory to the development of the intellectual powers? These and a host of other problems invite research.

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[1] See Bernheim, op. cit., I., Ch. VIII.

[2] See Beaunis, loc. cit., who found a phase of unconscious muscular memory.

[3] See Bradley: Mind XII., p. 579 seq.

[4] See Encyc. Brit., Art. Psychology, p. 61.

[5] Several recent writers consider the pedagogical aspects of memory. See especially Kay: "Memory, What it is and how to improve it;" C. G. Leland: "Practical Education;" Fauth: Das Gedächtniss; and Eldridge-Green: "Memory, its Logical Relations and Cultivation."

Finally we come again to the deeper philosophic questions. What is the genesis of the power of recognition? and what the explanation of this supreme mystery of memory?[1] Have we not in acts of recognition and comparison forms of consciousness that are not mere functions of its individual elements? What is the relation of attention to the conscious train?

The last question brings us to the front of the battle between the Associationists and the Apperceptionists. The former, under the lead of Bain in England and supported to a considerable extent by empirical studies in France[2] find nothing in the rise and succession of our ideas that may not be explained by the principles of association. The latter with Wundt and Ward at their head lay special stress upon attention and find higher conscious activities that get no adequate explanation from the laws of association.[3] Wundt maintains that apperception, the primal form of voluntary activity, is an essential characteristic of consciousness from the first, that it depends on the whole nature and past of consciousness, and that the will in its function of active apperception directs the conscious train. Recently the contest has extended to the experimental field. Dr. Hugo Münsterberg reports an extended series of experiments upon complicated mental processes the results of which in his opinion clearly refute this apperception theory.[4]

Thus the study of memory—as every psychological study sooner or later must—leads to the subject of attention, and to the deeper mysteries of con-

[1]Space forbids a discussion of theories of recognition and localization. For an excellent discussion of the subject and criticism of recent views, see an article by Fouillée, Rev. des Deux Mondes, July 1, 1885.
[2]See especially Binet's Psych. du raisonnement.
[3]See Ward, loc. cit., p. 41 seq.; and Wundt, op. cit., Bd. II, Ch. XX.
[4]See Op. cit., p. 64 seq.

sciousness; and here for the present this historical paper must end.

APPENDIX.

In closing the historical portion of this study I wish to thank the officials who have aided me at the Harvard and Johns Hopkins Libraries, at the Boston Public Library, the Peabody Library of Baltimore, and the Surgeon General's Library at Washington. I am also under obligation to many others, especially to Pres. G. Stanley Hall, at whose suggestion this work was begun, and to Dr. E. C. Sanford for invaluable suggestions.

I append a bibliography of the most important literature of the subject so far as I have been able to gather it. Only a few titles upon the Association of Ideas are given; and works upon mnemonics, except a few of special interest, have been omitted. Those interested in the subject can refer to the list of books given in Ersch and Gruber's encyclopedia, article *Gedächtnisskunst*, and to G. S. Fellows' bibliography in the American edition of Middleton's "Memory Systems New and Old." Literature upon the pathology of the subject also has been omitted for the most part. For this the articles upon *Aphasia* and *Amnesia* in the catalogue of the Surgeon General's Library should be consulted. Nearly all works upon the general subject of psychology have chapters upon memory. A few of the most important are mentioned in the following list as representative. Nearly all works upon Hypnotism also have some bearing upon memory. For the voluminous literature of this subject see Max Dessoir's *Bibliographie des modernen Hypnotismus*, Berlin, 1888.

Many references of minor importance already given in foot-notes are omitted. In a few cases I have mentioned works that I have not seen when I had reason to believe them of value.

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